

# PATENT SPECIFICATION

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## COMPLETE SPECIFICATION.

### Method of Bonding Aluminium and/or Aluminium Alloy.

We, BORG-WARNER CORPORATION, a Corporation organised and existing under the laws of the State of Delaware, United States of America, of 200 South Michigan Avenue, Chicago, Illinois 60604, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to a method of bonding aluminum and/or aluminum alloy surfaces and more particularly to a method of bonding in the absence of a corrosive flux.

Prior to this invention, fragile aluminum parts such as those making up heat exchangers, electrical terminals, commutator segments and the like were normally bonded either to themselves or to other materials by brazing or soldering as opposed to bonding by solid state diffusion. Brazing or soldering of these materials was necessary due to the fragile nature of the thin aluminum components and the danger of crushing through application of pressure. The brazing or soldering was normally accomplished by first preparing the aluminum surface with a fairly corrosive flux or cleaning material and thereafter causing the brazing metal to flow between the two surfaces to be bonded together. The flux or fusion promoting materials were normally applied either separately or as an integral component of the

brazing material. Such joining methods were economical and yielded sound joints, but it was virtually impossible to prevent the entrapment of flux which was generally a necessary ingredient in the process. The entrapped flux often led to premature failure of the structure by corrosion, especially when extremely thin parts were bonded together. It was not possible to bond by methods such as solid state diffusion due to the necessity of utilizing high pressures which tended to crush the very fragile, thin aluminum parts.

It has been desired to provide a method of bonding aluminum sheeting and aluminum parts by using well known and accepted alloys, such as aluminum-silicon, without utilization of oxide removing fluxes for preparing the surface prior to or during bonding.

A method has now been found of bonding together aluminium surfaces using conventional aluminium-silicon brazing alloys which does not require the use of corrosive fluxes and which does not require the application of pressure to the aluminium articles to be bonded together.

Accordingly, the present invention provides a fluxless method of bonding together two aluminium and/or aluminium alloy surfaces using an aluminium-silicon brazing alloy and a bond promoting metal selected from nickel, cobalt, iron, arsenic and silver which comprises bringing together in an oxygen free

inert atmosphere the surfaces to be bonded with the brazing alloy and bond promoting metal located between the surfaces or on at least one of the surfaces, increasing the temperature of the surfaces, brazing alloy and bond promoting metal so that a fused bonding material having as its constituents the brazing alloy and the bond promoting metal bonds together the aluminium and/or aluminium alloy surfaces, reducing the temperature of the bonded together surfaces to about 100°F. below the melting point of the bonding material and removing the bonded together surfaces from the inert atmosphere at this temperature.

The brazing alloy may be used in the form of a thin sheet or shim of metal onto the surfaces of which has been applied the bond promoting metal. In this embodiment of the invention the two aluminium and/or aluminium alloy surfaces to be bonded are brought together with the shim located between them and then subjected to heating in the inert atmosphere. In an alternative procedure the brazing alloy is applied as a coating to one or preferably both of the surfaces to be bonded together and the bond promoting metal then applied to the exposed surface of the brazing alloy. When the temperature of the inert atmosphere is raised to a sufficiently high temperature to cause melting and flowing of the bonding material having as its constituents the brazing alloy and bond promoting metal, on the surfaces to be joined together, the bonding material wets the joints and flows into the voids of the interface and forms smooth fillets at the surface intersections.

When the brazing alloy is a coating on the aluminium surface to be bonded and receives the bond promoting metal, the bond promoting metal can remain initially i.e. before the actual bonding operation takes place, as a coating on the aluminium silicon alloy, or it can be incorporated initially in the brazing alloy to give an alloy containing aluminium, silicon and the bond promoting metal. When the brazing alloy is used in shim form, the bond promoting metal forms a surface coating on the shim prior to the actual bonding operation.

It is preferred to use 0.1 to about 30% by weight of the bond promoting metal based on the combined weight of the brazing alloy and bond promoting metal.

Once the aluminium surfaces to be bonded, the brazing alloy and bond promoting metal have been brought together in the inert atmosphere, the temperature may be raised to about 100°F. below the melting point of the bonding material, and thereafter very quickly increased to the melting temperature of the bonding material. The temperature 100°F. below the melting temperature of the bonding material is normally

about 1000°F. This final 100°F. temperature increase preferably takes place within from about ten seconds to sixty minutes and conveniently within two minutes. The temperature is retained at the melting point of the bonding material (approximately 1100°F.) for a very short period of time, no greater than two minutes, to allow flow to occur between the joints and the bonded part is thereafter cooled to about 100°F. below the melting point of the bonding material in about five seconds to five minutes and preferably within two minutes. The heating, bonding and cooling is accomplished within the confines of the inert atmosphere. By inert, it is meant an atmosphere containing no gaseous materials that have a detrimental effect on the bonding action. It has been found that atmospheres such as argon, nitrogen, helium and hydrogen do not interfere with this bonding action. It has also been found that the bonding may take place *in vacuo*. The bonded parts are removed from the inert atmosphere after the cooling step to about 100°F. below the melting point of the bonding material.

The bond promoting metal, if applied as a coating on the brazing alloy, is ordinarily of the thickness of about one-hundredth of the thickness of the brazing alloy coating on the aluminium surface or alternatively about one-hundredth of the thickness of the brazing alloy shim, if one is used. When initially incorporated into the brazing alloy to give a modified brazing alloy, it is normally present in an amount from about 0.1% up to about 30%. When bonding takes place, the bond promoting metal reacts with and becomes part of the brazing alloy if it has not already been so incorporated and promotes wetting of the aluminium parts as well as flow of the alloy into the joints formed by the two aluminium parts that are joined together.

Utilizing the conventional aluminium-silicon brazing alloy, the bonding material, after the bond is formed, will normally contain 7.5 to 13% by weight silicon and trace amounts of other metals such as up to 0.3% by weight copper, up to 0.8% by weight iron, up to 0.2% by weight zinc, up to 0.1% by weight magnesium, up to about 0.15% by weight manganese, up to 4.5% by weight phosphorus and 0.1 to 30% by weight of the bond promoting metal, preferably nickel or cobalt, with the remainder aluminium.

The preferred bond promoting metal utilized in the bonding method of this invention is nickel, which has extremely good oxidation resistance, as well as high melting point, i.e. its melting point is higher than that of the brazing alloy. Also, nickel tends to exothermically react with the aluminium of the aluminium-silicon alloy. Nickel is also preferred because of its protective

nature which prevents corrosion of the base material. The other bond promoting metals specified above, particularly cobalt, have the aforementioned desirable qualities and may also be utilized.

The bond promoting metal, when applied as a coating to the brazing alloy, is normally deposited either on the alloy coated on the aluminium surface or on the metal shim, as the case may be, by a method such as vacuum deposition, electroless plating, or thermal decomposition. These methods are preferred coating methods because they prevent contaminants from interfering with the bond promoting metal.

The heating atmosphere in which the bonding may take place may be any suitable furnace which contains an inert oxygen-free atmosphere having a dew point of no greater than  $-30^{\circ}\text{F.}$  and preferably a dew point of  $-70^{\circ}\text{F.}$  The furnace may also, as mentioned, have means for evacuating all gas from the furnace, so that the bonding can be achieved *in vacuo*.

The following Examples are set forth to illustrate the method of this invention. However, they should not be taken as limiting the invention to the details disclosed. In each of the Examples, specific temperatures were used as well as specific atmospheres and this is not meant to limit that aspect of the method, but are mentioned merely for illustrative purposes.

#### EXAMPLE 1

A heat exchanger made of 1100 aluminium (i.e. containing at least 99% aluminium) consisting of fins, tubes and headers (non-clad) was bonded together by the method of this invention utilizing shim stock between those portions desired to be joined. The shim stock was aluminium-10 per cent silicon alloy, 0.005 inches thick. The shim stock was provided on its surfaces with a coating of nickel 30–50 microinches thick. The shims were placed around the tubes which were firmly fitted into the holes of the headers and other parts of the heat exchanger at surfaces to be joined together. The assembly was placed in a furnace having a nitrogen atmosphere with a dew point of  $-50^{\circ}\text{F.}$  The assembly was heated to  $1000^{\circ}\text{F.}$  within a period of about ten minutes and thereafter to  $1100^{\circ}\text{F.}$  (plus or minus  $10^{\circ}\text{F.}$ ) within  $1\frac{1}{2}$  minutes. The assembly was held at  $1100^{\circ}\text{F.}$ , the melting point of the bonding material for  $\frac{1}{2}$  minute. The heater on the furnace was turned off and the assembly was cooled to  $1000^{\circ}\text{F.}$  within two minutes and, at this temperature, removed from the furnace.

#### EXAMPLE 2

Heat exchanger parts consisting of tubes, fins, and headers were placed in contact with each other and bonded in accordance

with the method of this invention. The tubes were made from 50 S. aluminium, i.e. an aluminium alloy containing 1.2% magnesium, clad (only on the outside) with aluminium-10 percent silicon alloy, 0.001 inches thick. The headers were 50 S. aluminium, clad on both sides with aluminium-10 percent silicon alloy, 0.004 inches thick. The fins were 1100 aluminium, 0.004 inches thick and were not clad. The tubes were plated on the outside only (on the clad portion) with electroless coated nickel-phosphorus alloy of a thickness of 10 microinches. The headers were plated on both sides with electroless coated nickel-phosphorus alloy to a thickness of 40 microinches. The fins were not plated. The parts of the heat exchanger assembly were held in position by a fixture and the assembly was heated to a temperature of  $1000^{\circ}\text{F.}$  within a period of ten minutes. The assembly was thereafter heated to  $1100^{\circ}\text{F.}$  within two minutes and held at this temperature for approximately  $\frac{1}{2}$  minute. The atmosphere of the heating chamber was nitrogen gas having a dew point of  $-50^{\circ}\text{F.}$  The atmosphere was cooled from  $1100^{\circ}\text{F.}$ , the melting point of the bonding material, to about  $1000^{\circ}\text{F.}$  in about two minutes and the assembly was removed at this temperature from the furnace atmosphere.

#### WHAT WE CLAIM IS:—

1. A fluxless method of bonding together two aluminium and/or aluminium alloy surfaces using an aluminium-silicon brazing alloy and a bond promoting metal selected from nickel, cobalt, iron, arsenic and silver which comprises bringing together in an oxygen-free inert atmosphere the surfaces to be bonded with the brazing alloy and bond promoting metal located between the surfaces or on at least one of the surfaces, increasing the temperature of the surfaces, brazing alloy and the bond promoting metal so that a fused bonding material having as its constituents the brazing alloy and the bond promoting metal bonds together the aluminium and/or aluminium alloy surfaces, reducing the temperature of the bonded together surfaces to about  $100^{\circ}\text{F.}$  below the melting point of the bonding material and removing the bonded together surfaces from the inert atmosphere at this temperature.

2. A method according to claim 1 in which the temperature of the surfaces, brazing alloy and bond promoting metal is raised to about  $100^{\circ}\text{F.}$  below the melting point of the bonding material and is thereafter raised very quickly to the melting point of the bonding material.

3. A method according to either claim 1 or 2 in which the brazing alloy is used in the form of a shim of aluminium-silicon alloy onto the surfaces of which has been applied the bond promoting metal.